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# **Diagonal and Vertical Routing Protocol for Underwater Wireless Sensor Network**

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**Abstract**

Devolving an efficient routing protocol in Underwater Wireless Sensor Networks (UWSNs) is a challenge due to volatile characteristics of the underwater environment. In this paper, we proposed an end-to-end delay efficient routing protocol called DVRP (Diagonal and Vertical Routing Protocol for Underwater Wireless Sensor Network). In DVRP, the forwarding of data packets is based on the flooding zone angle by the sender nodes toward the surface sink. To extend the network lifetime, DVRP is deliberating the saving-energy of sensor nodes. The sensor nodes in the network make a local decision of data packets forwarding under the constraint of the flooding angle between them and energy status. Our results show that DVRP has better performance than other existing delay efficient routing protocols, in term of end-to-end delays, energy consumption, and data delivery ratios.

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**Keywords:** UWSN; DVRP; Residual Energy; Routing Protocol; Flooding Zone;

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**1. Introduction**

Recently, many researches on Underwater Wireless Sensor networks (UWSNs) have been conducted to support practical applications such as underwater exploration, underwater tactical surveillance and

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seismic monitoring. The applications of UWSN are becoming popular for exploring areas in the ocean which have resources like oil/gas, nourishment products, valuable minerals etc. Underwater wireless sensor network is used to prevent oceanic accidents like disastrous pollution, submarine detection, and tsunami warning. Although UWSN inherit some common properties of the terrestrial wireless sensor network, the radio signals employed in the terrestrial wireless sensor network are not applicable in underwater environments. The radio signals can propagate on long distance with low frequencies and less channel error rates, requiring large antenna and high transmission power. Hence the acoustic medium is employed in the underwater environment (Akyildiz, Pompili, & Melodia, 2005). Due to this employment, UWSNs have to face some distinct challenges. First, the available transmission speed shifted from the speed of light to the speed of sound and the speed of acoustic signals in water is five order magnitudes less than the speed of electromagnetic waves (Heidemann, Wei, Wills, Syed, & Yuan, 2006). Secondly, the bandwidth is totally depends on the distance due to high channel error rates and the high power absorption factors of acoustic signals. Thirdly, energy consumptions are different for both types of WSNs. The UWSN needs more power require than the terrestrial based sensor network due to volatile characteristics of the underwater environment. Also there is no mechanism available to recharge the battery in underwater environment or easily replaced. From an energy perspective, packet transmission is preferred on multiple small hops over the long links. Multi-hop data deliveries have been proven to be more energy efficient than a single long hop (Ayaz & Abdullah, 2009). It is observed that packet routing over more numbers of hops ultimately degrades the end-to-end reliability especially for the harsh underwater environment.

Due to the above mentioned issues, the literature shows that the existing routing techniques for terrestrial base sensor network are not applicable in UWSN (Jiang, 2008). The proposed routing protocols for land based wireless networks seem to be poor in performance for underwater sensor networks. Some present protocols developed for terrestrial networks are used in UWSN with little modifications. The above mentioned limitations claim for protocol precisely designed for UWSN. A lot of researchers have been concentrating on manipulative efficient protocols to acclimate to the core characteristics of underwater communications.

## 2. Related Work

Many routing protocols for UWSNs have been proposed for the last ten years. In this section, we are presenting some related protocols such as VBF, and DBR (Zheng et al., 2008). Vector Based Forwarding (VBF) protocol is designed to solve the problem of high channel rates in dense networks (Xie, Cui, & Lao, 2006). VBF used vector based forwarding mechanism to forward data packets from source to destination. A vector is computed from the source towards the endpoint and nodes inside the computed radius of the vector can only participate in communication. The constraints of VBF lie in the conjecture of localization of the sensor nodes. The selection of the forwarding nodes is based on the predefined radius of the vector. Due to this selection, the communication of nodes can affect the sparse network.

To solve the localization problem in UWSN, protocol was proposed such as DBR (Yan, Shi, & Cui, 2008). Although, it does not depend on the localization but it faces the problems of redundant packet transmission, void areas and the nonappearance of energy consumptions. The vertical movements are very little and normally ignored (Nicolaou, See, Peng, Jun-Hong, & Maggiorini, 2007) in UWSNs, due to the same depth of the sensor nodes. The packets are forwarded in DBR based on the depth of nodes. Nodes with the smaller depth can only participate in the process of data packet forwarding. Due to this type of forwarding, the nodes with smaller depth die earlier than other nodes in the network. It also can cause to increase the cost of the network and more energy consumption.

### 3. Problem Statement and contribution

The horizontal communication between the sensor nodes on the same depth levels is caused to increase the routing data path from lower layer nodes to the surface sinks deployed on the surface. The large data routing path might be the issue that increase end to end routing delay in an underwater environment as well overhead for consumption. In DVRP, it tries to reduce or overcome the horizontal communication between the sensor nodes on the same depth levels in underwater environments. The angle based flooding architecture is used in DVRP to overcome the horizontal communication in UWSN. The anchored nodes flood the sense data towards upper layer nodes using the formula  $\theta = 90 \pm 10K$ , to calculate the flooding zone where the angle of the zone is always greater than zero and less than  $\pi$ . This condition is applied to execute the flood of data packets in diagonals or vertical form gradually, because we know that the distance covered in the vertical direction or in diagonals toward the destination in underwater is always smaller than the distance covered even one hop is involved in horizontal communication to the sink on water surface, as proved in the Figure. 1.

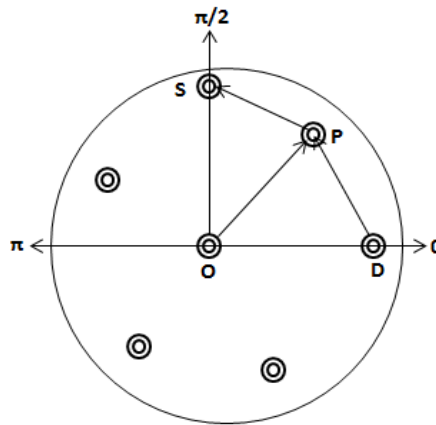


Figure 1: DVRP angle base architecture

In Figure 1, it is illustrated that O, D and P are ordinary floating nodes and S is the sink on water surface. The nodes O and D on the same depth level from the surface sink and the angle between them is zero and  $\pi$ .

Node O has a data packets and ready to send toward sink. Therefore these are some possible routes for node O, to send data packets toward the sink node. The first route is, O to D, D to P and P to S. The Second route, O to P and P to S. Third route, O to S, through this route the node O can directly send data packets to the sink node. Here we only consider the first two routes, to compare the covered distance by data packets toward the sink node. If node O sends data packet to node D and node D forward data packets to upper layer node P. Finally, node P forward data packets to the sink node S. Due to this selection of the data path, the data packets will cover long data route toward the sink node due to the involvement of horizontal communication link with node D. However, node O can directly send data packets to node P, which is diagonal to node O and near to the sink node.

By using the theorem triangular inequality, we proved that the distance covered by the data packets through vertical or diagonal path to the destination is always smaller than the distance in which horizontal path is exist. This is due to the presence of a horizontal peer link between the communication nodes. Here O, P and D are considering as a coordinate of the triangle.

From the triangle  $\triangle ODP$

$$|OP| < |OD| + |DP| \quad (3.1)$$

Equation (3.1) shows that the sum of two distances is greater than the third distance. Hence it's proved that if data packets send by using the route  $|OD| + |DP|$  will cover the large distance as  $|OP|$  route.

By adding  $|PS|$  on both side of equation (3.1)

$$|PS| + |OP| < |OD| + |DP| + |PS| \quad (3.2)$$

From equation (3.2), it is clear that the vertical or diagonal communication toward the sink node is better than the involvement of horizontal communication between nodes in the underwater wireless sensor network. So it is also proving that the flooding of data packets by the nodes within the calculated zone that has maximum angle is always greater than zero and less than  $\pi$ , can provide vertical or diagonal communication in UWSN. Therefore, nodes on the same depth level from the sink node and the angle between them is zero and  $\pi$ , could not communicate to each other, due to the calculation of flooding zones, until we allow the horizontal communication.

### 3.1. Data Packet Forwarding

In this phase, node forwards the data packets toward the surface sink. The forwarding process is as follows. The node has a data packets and it's ready to be sent. First, the node will calculate its flooding zone by using the basic formula  $\theta = 90 \pm 10K$ . The purpose of this flooding zone is to prevent the flooding on the whole network. The node will flood the Hello Packets (HP) within the flooding zone area and wait for Hello Reply (HR). If HR is received, the node will forward the sense data packets to the corresponding nodes. The nodes in the flood zone can only reply of HP. If node could not receive HR within the calculation time, the node will use the next value of  $\pm K$  in the initial formula to increase its flooding zone until the basic condition meets ( $0 < \theta < \pi$ ). The range of value for variable K is (1, 2... 8) (Ali & Jung, 2012). The largest value of K is 8 to prevent the horizontal communications between the sensor nodes. Here it is important to note that nodes can use random value of variable K, to increase the size of flooding zone. The randomness of K value is more helpful to control the end-to-end delays and as well as power consumption of the nodes. The selection of random values of K depends on the movement of nodes.

- If a node receives a very small number of Hello Reply. Therefore, nodes will consider the movement is slow. So nodes will use a large value of variable K to increase the flooding zone.
- If a node receives more number of Hello Reply. Therefore, nodes will consider the movement is fast. So nodes will use a smaller value of variable K to increase the flooding zone.

Let us take Figure 2 as an example. The nodes are deployed from the surface to the bottom. Sinks are on water surface and consider static after being deployed. The floating nodes are deployed with different levels of depth using the bouncy control mechanism and only consider horizontal movements on floating nodes. The vertical variation is very little and normally ignored. The distance between layers is 500m (Caruso, Paparella, Vieira, Erol, & Gerla, 2008). The node A has data packets and is ready to be sent. The node A defines its flooding zone area by adding the K value on both sides of its base angle 90. After defining the zone, the node A sends HP in the define zone. The node C is in the zone. The node C will calculate its priority on the bases of its own energy status and layer number. Node C will reply to HP with its calculated priority.

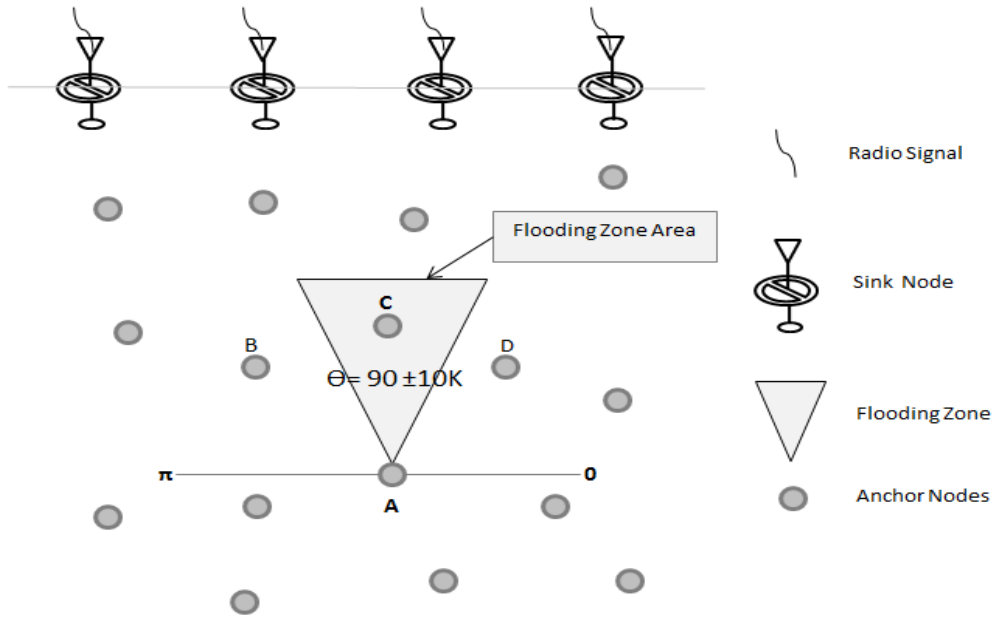


Figure 2: Data Packet forwarding mechanism

The Node A will check the priority of node C and send bursts of data packets to node C with the highest priority to become the next forwarder of these data packets. Now, node C is a qualifying node to become the next data packets forwarder. Here, we are assuming that the nodes in the flood zone will only reply to HP. In the case of multiple nodes in the flood zone, all nodes will reply of HP with their calculated priorities and the sender node will choose the best next forwarder based on received information in hello reply.

### 3.2. Data Packet and Multiple Forwarding control

As mentioned in the previous section, DVRP uses a flooding base approach. So it is very possible that many nodes are qualified candidates to forward a data packet at the next upper layer. The high collision and high energy consumption will be the result if all these qualified nodes try to flood the data packets. Consequently, to decrease the collisions as well as energy consumption, there is need to be controlled the forwarding nodes in the network. Moreover, due to the inherited multiple-path feature of DVRP multiple nodes may receive the same packet. Therefore; nodes can forward data packets multiple times. To get better energy efficiency, ideally only one node needs to flood the data packet. To do so, we introduced the concept of multiple queues. To save energy as well as to reduce collisions, there are two major reasons needed for multiple queues. One is that multiple nodes may forward same data packets. The other is that a node may send a same packet many times (Yan, et al., 2008). The priority queue is used to reduce the forwarding nodes and control the number of forwarding paths. For the second problem, packet history buffer is used in DVRP to ensure that a node forwards the same data packet only once in a certain time interval. A maximum of 50 data packets can be kept in the history buffer .When the buffer queue is full, new packet will replace the least used packet. The priority queue only contains the values to calculate the priority for next forwarder on the basis of its layered number and energy status.

#### 4. Results Evaluations

Network Simulator was used to evaluate the performance of DVRP. In our simulation, 300 sensor nodes (both sink and floating nodes) were deployed in 3D area of (800m × 800m × 800m). Multiple sinks are used at water surface and all sinks are static having a support of both (Radio, Acoustic) types of communication (Jornet, Stojanovic, & Zorzi, 2008). The distance between the layers of floating nodes can be up to 500m. In this experiment, sink nodes is considered to be static after deployed but remaining nodes are floating in nature and we ignore the vertical movement of floating nodes. The horizontal movement was considered between the floating nodes due to different water current up to 1-4m/s at fixed notions. End -to-end delay, data delivery ratio and energy consumption was considered three matrices to evaluate the performance of our routing protocol.

The performance of DVRP was checked by different number of packets generated in the network. Figure 3 (a) illustrates the delivery ratio with different number of data packets. The delivery ratios are almost the same in the dense network. The result shows, with the sparseness of nodes the variation is slow. With more number of data packets and few numbers of nodes in the network, sometime may cause to increase data packets in the buffer which results in discarding them. Figure 3 (b) presents the difference in end-to-end delays when the numbers of packets in the network are increased. The result shows that, the network can be handled easily when 60% more data packets are generated in the network. These delays are reasonable, when the generated data packets are double.

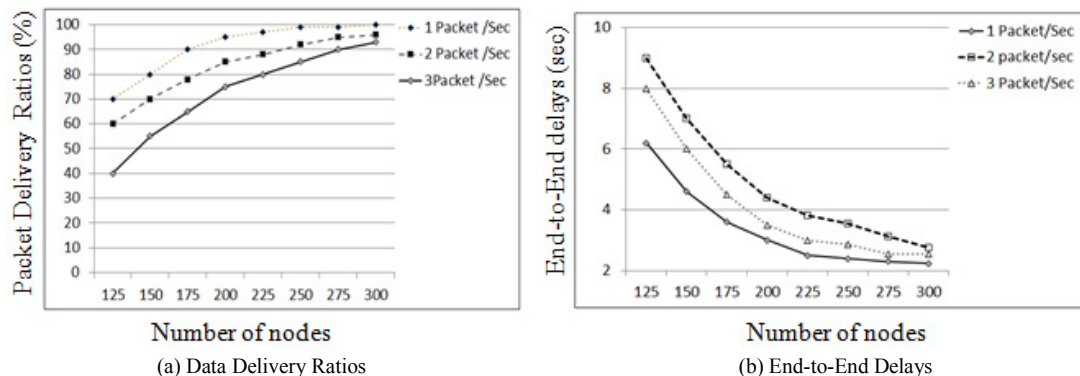


Figure 3: Performance of DVRP with different number of data packets

Every node in DBR, get a decision on the base of its current depth to forward data packets. A node has a data packet and its ready to be sent, first node compare its current depth with the embedded depth in receiving data packets. If its current depth is less than the sender's depth, node forward the data packets otherwise discarded the packets. DBR has some serious issues as compared to DVRP like it is possible that multiple nodes can have smaller depth levels and at the same time these nodes forward data packets, which not only can cause collisions in the network but also increase the energy overhead.

Further we compared DVRP with DBR to evaluate the performance. First we compare the data delivery ratios with single sink and multiple sinks as shown in Figure 4 (a). With multiple sinks, we found that both algorithms (DVRP, DBR) provide almost the same results with the density of nodes. As the number of nodes starts to decrease the delivery ratios of DBR also start to decrease while it has less effect on the delivery ratios of DVRP. It happens with DBR due to its greedy mode, even number of nodes are available in network with high depth levels but cannot participate in forwarding of data packets.

The data delivery ratios of DVRP and DBR with single sink, which is placed at the center of the

surface, the result shows that the delivery ratios of DBR are more exaggerated than DVRP. It is again due to the greedy mode of DBR, nodes only forward data packets to water surface but not forwarding it towards the sinks.

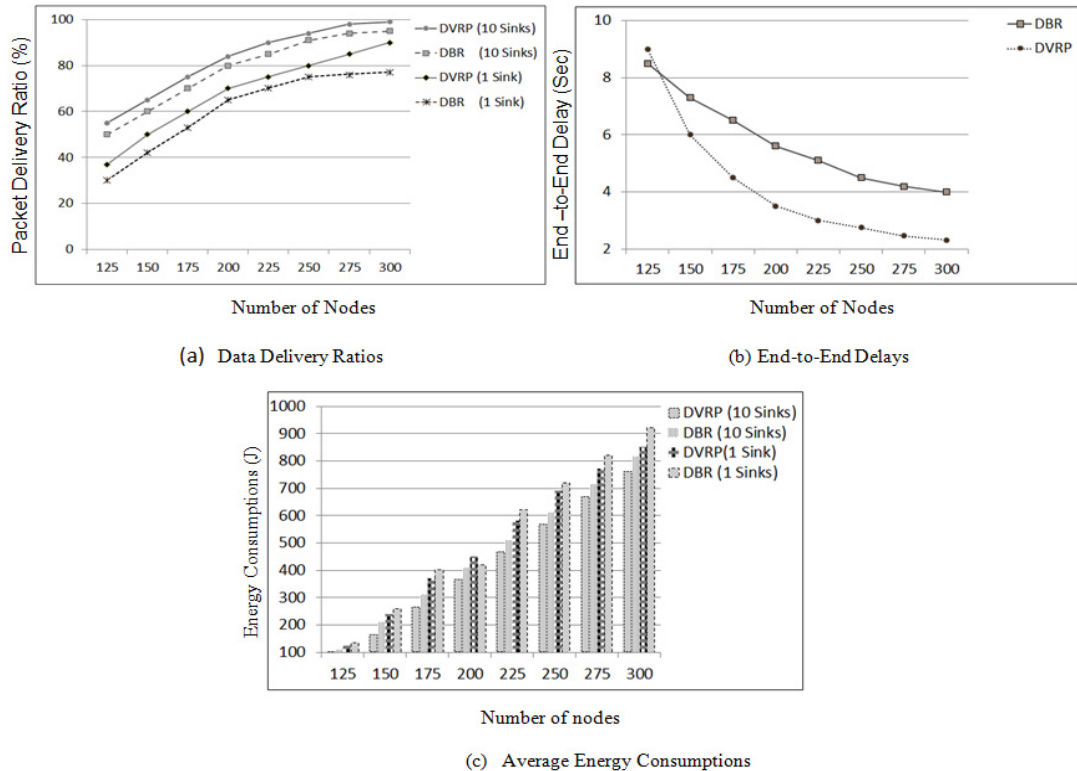


Figure 4: Comparison between DBR and DVRP

Figure 4 (b) shows, the comparisons for end-to-end delays between DVRP and DBR. Here DVRP delivers data packets with less end-to-end delays when reasonable sensor nodes are available in the network. It is only due to the holding time used in DBR. On the other hand DVRP only used angle based zone to flood the data packets and every node can forward data packets immediately.

Further we compared energy consumptions in Figure 4 (c) with different number of sinks. First we check with less number of nodes and the results were almost similar but when the number of nodes starts to increase the difference in energy consumptions start to increase. DBR uses the broadcasting for every data packet in greedy fashions and it increase the energy consumption with a dense network for the same data packets. In DVRP, the concept of angle base zone is used to perform flooding of data packets. The nodes will calculate flooding zone and flood the data packets within the define zone.

## 5. Conclusion

In this paper, we have proposed Diagonal and Vertical Routing Protocol (DVRP) to handle some critical routing issues in UWSNs. DVRP is scalable and efficient for end-to-end delays and energy consumption. We have found that, DVRP relies on the flooding base technique to increase the reliability of the network. However the number of nodes which flood the data packets is controlled by calculating



the angle for flood zone to prevent the flooding over the whole network. The flooding zone is adjusted using layer by layer manner through angle base technique among the upper layer nodes. The novelty of our proposed protocol is that it does not depend on location information and as well as there is no need to maintain the complex routing tables. It is very easy to add new nodes in the network at any time and any location. The real beauty of DVRP is that, delivery ratios are not much affected with the density or the sparseness of nodes. The simulation results show that it is better for long term and real time applications. In the future, we are planning to increase the number of evaluation metrics to investigate the relative performance of the protocol.

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